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STRATIGRAPHY OF THE WAVERLY FORMATIONS OF CENTRAL AND SOUTHERN OHIO (*Continued*)

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PART II

CUYAHOGA FORMATION (*continued*)

THE SCIOTO VALLEY SHALE FACIES

Extent and Thickness.—The Scioto River from Chillicothe to Portsmouth flows roughly along the axis of this area. Here the Cuyahoga is constituted almost entirely of bluish-gray clay shale with only an occasional sandstone bed. To the eastward, as the margin of the Hocking Valley conglomerate facies is approached, sandstones become more numerous and increase in thickness. A similar increase in sandstone content is experienced to the westward, as the Vanceburg sandstone facies is approached. These transitional sandstones are, however, of a different type on opposite sides of the shale area. On the eastern side are found hard, coarse sandstones (but finer grained than the Hocking Valley sandstones) that are peculiarly harsh to the touch; they are reddish-brown on the outcrop, light greenish-blue under cover, and *Spirophyton* is not present to any extent. Beds of this type persist as far west as the Scioto River, where they may be four or five feet thick, and some of the beds can be traced for several miles. On the western side of this shale facies, the sandstones are of the type which characterizes the Vanceburg facies, to be described presently, but distinguished particularly by their soft, clayey nature, light yellowish color on the outcrop but blue-gray under cover, and abundance of *Spirophyton*. One member only of the latter type persists any considerable distance into the shale area, the Buena Vista member, and it may be found in some sections east of the Scioto River in the presence of sandstones that have obviously been derived from the eastward, but even in the same section each exhibits the characteristics of its respective type little changed.

The Cuyahoga over the shale area is not as thick as in the Hocking Valley facies. Between Chillicothe and Waverly it is about 300 feet thick and at Portsmouth about 300 or 320 feet. West of the Scioto River near Portsmouth it falls to about 260 feet.

Members.—Three members are distinguished. At the base is the *Henley shale member* which apparently attains a thickness of over 200 feet. This is succeeded by the *Buena Vista sandstone member.* Since both are recognized in the Vanceburg sandstone facies, their description is better reserved for that place.

The name *Portsmouth* is applied to the upper shale member from Portsmouth, where it is excellently exhibited on both sides of the Scioto River, and on the Ohio River above the town. At the "Two-Mile Hill" at Portsmouth it is 253 feet thick, but this decreases to the northward and westward. The Portsmouth shale is the equivalent of the three upper members of the Vanceburg facies. It is impossible, at present, to present correlations between the members of the Scioto Valley shale facies and those of the Hocking Valley conglomerate facies to the eastward. All that can be suggested is that the Buena Vista sandstone is not the equivalent of any one of the four members distinguished there; its horizon is probably near the middle of the deposits in the Hocking Valley. Further, it appears that the upper part of the Portsmouth shales at Portsmouth—how much is not known, but perhaps 50 feet or more—is the stratigraphic equivalent of the lower part of the Byer member of the Logan formation only six miles up the Ohio River at Sciotoville.

THE VANCEBURG SANDSTONE FACIES

Extent and general nature.—This is confined to the western parts of Scioto and Pike and the southwest corner of Ross counties, with some extension into Adams County. The facies proper lies well west of the Scioto River. The thickness of the Cuyahoga appears to be about 250 feet, of which the lower 150 feet or more are made up largely of sandstones, the upper 100 feet largely of shale.

The deposits which distinguish this facies differ greatly from those in the two sandstone and conglomerate facies just described. They consist of alternating beds of exceedingly regular sandstone and shale. The sandstones are usually from 6 or 8 inches to 18 inches in thickness, although they exceptionally attain 4 or 5 feet; they are very uniformly fine grained, blue-gray in color when unweathered, and persistently uniform in thickness for considerable distances. The shales not uncommonly are mere partings between these beds, but they may equal or exceed the sandstone beds in thickness. At McDermott the thin sandstone and shale beds are known to hold their characteristics individually over almost a square mile. The shales are thicker at the bottom and at the top and the persistent occurrence of a considerable amount of red shale in the lower part is one of the characteristic features of this facies and an unusual one in the Waverly.

The upper surface of each stratum of sandstone is covered by *Spirophyton* markings, the tubes of which penetrate downward through the upper 4–8 inches in infinite numbers. The under surface of each sandstone is usually traversed by many raised lines and elongate rootlike ridges in various degrees of prominence which are merely the casts made by the sand settling in the scratched and gouged upper surface of the underlying shale partings. These structures indicate a peculiar cycle of events that was repeated many times during the accumulation of the deposit: (1) accumulation of sands to a thickness of a foot or two; (2) period of quiet and invasion of the sandy floor by myriads of fixed worms (if *Spirophyton* is correctly interpreted as a worm tube); (3) deposition of a thin bed of clay mud and extermination of the worms; (4) intervention of some agent, probably bodies floating or trailing in shallow water, which scratched the muds but never, so far as observed, to a depth of over an inch; this completed the cycle and sands were again laid down. This was repeated many times but it is more striking in the lower part of the sandstones, where the shales are reduced to mere partings.

The deposit is marine, as is shown by the occasional finding of a sandstone bed which differs from the others only in the presence of a normal marine fauna of brachiopods, gastropods, cephalopods, lamellibranchs, etc., in very great abundance often only for a few square feet; the composition and structure of such a deposit suggest that this accumulation where found was accomplished through current-action.

The deposits of this facies pass into the shales of the Scioto Valley shale facies to the eastward by disappearance of the sandstones. This transition takes place rather abruptly and practically all of the beds disappear simultaneously except those of the Buena Vista member, which persists far into the shale area. The original western margin of the Vanceburg facies in Ohio has been removed by erosion.

Five members can be recognized, of which all are persistent over the area of the facies, except the topmost, which has been removed by erosion at points in Pike and Ross counties. Although these members appear to be distinct stratigraphic units over much of the area, near the margins of the facies where the sandstones are disappearing certain of the boundaries obviously become of uncertain stratigraphic significance.

The Henley shale member is named from Henley, Scioto County. In the area of maximum development of the Vanceburg type of sandstones, it consists of alternating gray and red shales, but the red color disappears to the eastward, together with the sandstones of the facies. Along the western boundary line of Scioto and Pike counties this member gradually increases in thickness from 5½ feet at Buena Vista and 9 feet at Vanceburg to 34½ feet at Bainbridge in Ross County. Eastward and northeastward from this line of sections in the Scioto Valley shale facies the thickness increases rapidly, especially to the eastward. Along the Scioto River the thickness increases from 55½ feet at Rushtown in Scioto County to 89 feet near Summit in Ross County. Several miles east of Piketon in Pike County, its thickness has increased to 226 feet, if the superjacent Buena Vista sandstone is correctly identified. The rapid westward thinning of this basal portion of the Cuyahoga is believed to indicate that the Cincinnati dome was an appreciable topographic feature on the shallow sea-floor of that time. There is, however, no physical evidence of erosion of the underlying thin Sunbury shale prior to its accumulation.

The name *Buena Vista* has been adopted for the second member in the Vanceburg facies.[1] For many years the village of Buena Vista was the center of extensive quarrying. The basis of the industry was a relatively thin sandstone member a few feet above the base of the Cuyahoga. Since the product was largely marketed in Cincinnati, the member came to be known as the "City ledge." It is to this member and its continuation over Scioto, Adams, Pike, and Ross counties that the name Buena Vista is here restricted.

The Buena Vista consists of sandstones of the type just described as characteristic of the facies. It is not, however, of the same quality, structure, and thickness in all parts of its area. Along the western margin of Scioto County it is usually from 3 to 6 feet thick and consists of from one to four distinct sandstone beds. Eastward from this and over the ever-thickening Henley shale,

[1] This name was first proposed by Edward Orton in his "Report on Pike County" (*Geol. Surv. Ohio*, II, Part I [1874], 626), where the lower 50 feet of the Cuyahoga formation was separated as the Buena Vista member. "As the most valuable of the building rock, however, that is furnished by this part of the series in southern Ohio occurs within 50 feet of the slate [Sunbury], these 50 feet next above the slate may be somewhat arbitrarily taken as a subdivision." Prosser has fully recounted the history of this usage and variation in usage of the term by Orton and has himself adopted it in the same sense as originally used (*Am. Geol.*, XXXIV [1904], 341, 342). It can readily be shown, however, that any member arbitrarily established on the lower 50 feet of the Cuyahoga over central and southern Ohio is wholly without foundation in fact. Stratigraphically there is no such member. The lowermost 50 feet will not include all of the valuable building stones, if this were an acceptable criterion for the establishment of such a member, since it does not include the stone at the only locality where such stone is now being worked, McDermott. The sediments forming the lower 50 feet from point to point are not even always similar; in some places it is sandstone, in others it is shale. It becomes necessary to redefine the term Buena Vista if it is to be used at all, and in the present statement it is applied to the "City ledge" of the quarrymen at Buena Vista, and its continuation throughout western Scioto and Pike counties. Orton has on one occasion (*Geol. Surv. Ohio*, V [1884], 602) used the term Buena Vista in this sense. Elsewhere he has used it apparently to denote the particular bed which he erroneously supposed to be the equivalent of the City ledge ("Report on Pike County," *Geol. Surv. Ohio*, II, Part I [1874], diagrams between pp. 618 and 619). Prosser, too, in an earlier publication used the term similarly (*Jour. Geol.*, X [1902], 289–91). The term thus redefined is not, then, used with a wholly new meaning.

The adoption of the term in Ohio with either of the meanings outlined antedates its application by H. D. Campbell to a formation in Virginia (*Am. Jour. Sci.*, 4th ser., XX [1905], 445–46), as pointed out by Prosser (*Am. Jour. Sci.*, 4th ser., XXI [1906], 181–82).

it increases in thickness to about 25 or 30 feet along the west side of the Scioto River well within the Scioto shale facies. Simultaneously the number of component beds increases. Farther east than this on the east side of the Scioto River, and northward over western Pike and southwestern Ross counties, its beds become more shaly and worthless. It remains, however, so far as traced, much the same type of deposit as characterizes the Vanceburg facies, even where, on the eastern margin of the Scioto shale facies, it becomes intertongued between those sandstones of a wholly different type that are clearly the western fringe bordering the Hocking Valley conglomerate facies. At the most easterly point where it was observed, however, several miles east of Piketon, the component beds are much thicker than a mile or two to the westward, and there is evidence that, as the Hocking Valley area is approached, the member increases in importance.

Westward from the western margin of Scioto County the Buena Vista member continues to thin, and within two or three miles of the zone where it is from 3 to 6 feet thick and economically important, it is less than a foot in thickness. It has not been traced westward beyond this but it probably thins out entirely. This is near the western limit of its outcrop belt.

The Rarden shale member is named from Rarden, Scioto County. It is not recognized outside the Vanceburg facies, since opportunity to identify its upper limit is lost with the disappearance of the overlying sandstones. Like the Henley member, it consists of alternating red and gray clay shales. At Vanceburg, Kentucky, it is 8½ feet thick; from here northward and eastward it increases in thickness to 28 feet at Buena Vista, 27 feet at Rarden, 50 feet at Bainbridge, and about 58 feet at Elm Grove in Pike County on the extreme eastern margin of the facies.

Along the western margin of the outrcop belt, in Adams County, where the Buena Vista member becomes insignificant, this member probably rests on, and is indistinguishable from, the Henley member, although no section of precisely this type has been seen. At Mineral Springs, Adams County, there are something over 40 feet of red and gray clay shales at the base of the Cuyahoga, with a single 3-inch sandstone in the lower part, believed to be the Buena Vista. This is the nearest approach to this condition observed.

The Vanceburg member consists of typical sandstones of the facies. It is best developed in the vicinity of Vanceburg, Kentucky (from where the name is derived), and Buena Vista. Here the member is about 150 feet thick and on the whole the sandstones are thicker than the intervening shales. Both northward and eastward the shales become relatively more important, and at Bainbridge they form much the larger part of the member. These sandstones give place by transition to the shales of the Scioto Valley facies, but rather abruptly, along the line indicated on the map.

The Churn Creek member is seldom seen and then not well. It consists of argillaceous shale with an occasional thin sandstone and the deposits of the Vanceburg member pass into it gradually. Except for the difference in relative amounts of sandstone and shale it is of the same type. It appears to be between 50 and 100 feet thick, but no section has been seen which admits of determination of this point. It is present in Ohio only in western Scioto and eastern Adams counties, being removed farther north, and only in the vicinity of Buena Vista is the Logan formation found overlying it. It is named from Churn Creek in the southeastern part of Adams County, on the divide between which and the head of Lower Twin Creek good outcrops are seen in roadside ditches.

THE CUYAHOGA FORMATION IN KENTUCKY

It has been shown how the outcrop belt of the Cuyahoga passes southwestward diagonally across the five successive facies from the Toboso facies in central Ohio to the Vanceburg facies at the Ohio River. From the Ohio River the outcrop belt of this formation continues southwestward into Kentucky. The writer has seen it at various points as far as the center of the state[1] but is not prepared to discuss it from such observation. Morse and Foerste have published sections from this region that indicate something of the nature of the formation,[1] but their sections are for the most part of the Bedford, Berea, and Sunbury formations. At a few localities only is more than the very base of the Cuyahoga described and in no one section is the entire formation distinguished.

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[1] Under grant from the Esther Herrman Research Fund of the New York Academy of Sciences.

From these observations it appears that there lies southwest of the Vanceburg sandstone facies in Kentucky an area in which the Cuyahoga is largely a bluish argillaceous shale, and that the margin between them lies somewhere between 5 and 20 miles south-southwest of Vanceburg, Kentucky. Not only do the sandstones that characterize the Vanceburg facies largely disappear, but the red shales that are equally characteristic are replaced by bluish ones. A sandstone member of precisely the same character as the Buena Vista member on the eastern side of the Vanceburg facies and occupying about the same position in the formation is continued to the southwestward into this shale facies. It is quarried at Farmer, Freestone, and Rockville, about 30 miles southwest of Vanceburg, where it is about 25 feet thick and is reported underlain by from 1 to 11½ feet of soft shales. Morse and Foerste consider this sandstone the top of the Buena Vista member, using that term with the sense given it by Prosser. Although it closely agrees with the Buena Vista member (sense adopted by the present writer) in structure and position, this correlation cannot, as yet, be considered established. Within 10 miles farther to the south-southwest, this member appears to pass into shales and the Cuyahoga is almost entirely a shale, but apparently with diminished thickness.

The question may well be raised whether these shales are the equivalent of the Cuyahoga formation, as it has herein been described, in southern Ohio. A careful tracing of the sandstone members in the lower part is necessary to an opinion as to whether the base is approximately the same. As to the upper limit, *Allerisma winchelli* was found by the writer in the overlying yellow sandstones, perhaps 100 feet above the shales, near Morehead, Kentucky. This species is, as far as known, confined to the Byer and Allensville members of the Logan. This would indicate that the lower 100 feet at least of these sandstones in northern Kentucky, within 45 miles of Portsmouth, are the approximate equivalent of the Byer member in southern Ohio, which there overlies the Cuyahoga or in part passes into the topmost beds of the Cuyahoga.

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[1] "The Waverly Formations of East Central Kentucky and Their Economic Values," *Kentucky Geol. Surv., Bull. 16* (1912), 76 pp.

PALEOGEOGRAPHY OF THE CUYAHOGA

The Toboso and Hocking Valley conglomerate areas.—Herrick thought that the material composing the Black Hand conglomerate came from the northeast.[1] Stevenson writes of the pebble material of the "Logan" (Orton's usage, Black Hand and Logan of this paper) as follows: "They can hardly have come from the north, for there the upper Logan, Reid's Olive Shales, is very fine in grain, while farther south it becomes coarse, as it is in northwest Pennsylvania, east from Reid's localities. It is equally improbable that the pebbles come from the east, for the deposits become finer eastward toward the central line of the basin, beyond which they become coarser. The sands must have come from the western side."[2]

The immediate source of the conglomeratic material in the Cuyahoga of central Ohio undoubtedly was to the south-southeastward. Lamb's observations in northern Ohio on conglomerates of undetermined horizon indicate the same direction as the source of the material.[3] It is not possible at present to state under precisely what conditions the conglomerate sandstones of the Toboso and Hocking Valley facies were deposited, but it is the writer's opinion that they are the result of deltal action under marine conditions. The structures observed, however, do not in any way correspond to the structures suggested by Barrell as criteria of such an origin.[4]

These sandstones were deposited under conditions of strong current-action which swept pebbles up to an inch in diameter to their present position; which laid down thick beds over wide areas at an inclination of 5° to 10° (much steeper than the foreset beds of the large deltas of the present, according to Barrell); which generated in these beds cross-bedding of the most pronounced kind, of both the irregular cut-and-fill and the regular inclined-bedding types; which, over extensive portions of the eastern side of the Hocking Valley area, dumped coarse conglomerate to a thickness up to 50 feet or more at an angle of from 15° to 20°, with northeasterly dips.

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[1] C. L. Herrick, *Bull. Sci. Lab. Dennison Univ.*, II, Part I (1887), 9, 10.

[2] J. J. Stevenson, *Bull. Geol. Soc. Am.*, XIV (1903), 91.

[3] G. F. Lamb, *Ohio Naturalist*, XIV (1914), 344–46.

[4] Joseph Barrell, "Criteria for the Recognition of Ancient Deltal Deposits," *Bull. Geol. Soc. Am.*, XXIII (1912), 377–446.

The material on the whole is far coarser than that observed, according to Barrell, at present in the deltas of large rivers, and the current-action was far stronger. It is the writer's opinion that the sands of the more gently inclined beds (5° to 10°), where cross-bedded as in the Black Hand member of the Toboso facies, were spread out on the ocean floor in part by the assistance of wave-action and shore currents, but chiefly under the direct influence of strong currents from a river mouth or other source of sand-laden waters. Where cross-bedding is reduced in amount and magnitude, as in the beds of the Fairfield member, the stream current is believed to have been relatively less important and the wave and shore currents more important. Much of the Black Hand member of the Hocking Valley facies has been laid down, according to this interpretation, under the former conditions, but large portions, especially near the margins of the facies, under the latter conditions. Where steeply inclined conglomerates with dips of 15° to 20° are extensively developed, as in the eastern portion of the Black Hand of the Hocking Valley area, it appears that the material was dumped into a protected area of relatively deep water, where it formed a face at the angle of repose for such material in water, uninfluenced by waves or bottom currents. A glance at the map will show that the eastern margin from Lancaster to Logan must have been, under the interpretation given these facies, well protected, and it is here only that such extensive steeply inclined bedding is found. It seems necessary to believe that the wave-action was far weaker than that obtaining along the seaward faces of present-day deltas facing the open ocean; otherwise this material would have been spread laterally along shore and outward to such an extent that the Toboso and Hocking Valley facies would not have remained as sharply defined, individual lobes.

The structures observed in the cross-bedded conglomerate, whether steeply or gently inclined, are precisely the ones that

Barrell regards as indicative of river-laid sands,[1] and not indicative of wave-laid or wave-current-laid sediments; but that they were accumulated under subaquatic and probably submarine conditions is indicated (1) by the rapid lateral passage of the members into marine beds; (2) by the presence of oscillation wave ripples on an inclined bedding-plane between sharply cross-bedded conglomeratic sandstones, in one case known over several acres and through a vertical range of some 30 or 40 feet; (3) by the presence of worm trails (*Scalarituba*) that are common in undoubtedly marine Waverly sediments; and (4) by the occurrence of thin beds of soft clay shale interbedded with the inclined sandstones and similarly inclined. No mud cracks have been seen and there is none of that evidence of oxidation seen in highly colored red beds, which may be the result of, and commonly are held to suggest, subaerial accumulation. To be sure, red sandstones occasionally appear, but they are not confined to one bed so much as to a limited locality where a considerable thickness of beds may be involved, and where, it appears, some other local condition or source must be involved.

The structures observed are very like those that would be expected in bars or spits built into deeper water, such as Sandy Hook, but perhaps with more cross-bedding; however, from the geographic distribution of the conglomerate masses along the belt of outcrop it is at present impossible to entertain this view. It does not appear possible for two such bars as the Hocking Valley and Toboso facies would imply to be built alongside of and parallel to each other simultaneously; and the results obtained so far all indicate that they were accumulated simultaneously.

As has been pointed out, there is distinct lobation in the Hocking Valley area; east of the Hocking River in southern Fairfield County, and traversed by it in Hocking County, is a secondary mass of conglomeratic sandstone that is immediately adjacent to the main mass of the facies, and it appears very probable that under cover of the Coal Measures to the southeastward the Toboso and Hocking Valley masses may become contiguous in the same way and prove to be only larger lobes of a yet greater development of coarse material. If the interpretation is correct that these sediments are of deltal origin, then the outcrop belt in central Ohio appears to be that portion of the floor of a marine interior sea which lay just off the front of a delta and was invaded by lobes from it. It appears, however, that no portion of the outcrop sediments have been deposited subaerially. The shoreline perhaps lay at no great distance to the southeastward, possibly only a few miles. The sea must have been one of quiet waters compared with the open ocean, otherwise the waves would have destroyed the fairly sharp lines of the facial boundaries.

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[1] *Op. cit.*, pp. 430–32.

It is, perhaps, unexpected to learn that these conglomeratic sandstones had their origin in the Appalachians. The paragraph quoted above from Stevenson's carefully considered work indicates how far it was from the thought of one who knew the whole problem. Certainly the deep-well records so far published from southeastern Ohio lead one to believe that the corresponding portion of the column under cover is largely shale. Well records, however, are very unreliable except when samples are taken, and usually but little attention is really paid by the driller to any except the few horizons that are well known to him and are used by him as guides.

It appears probable that, in certain places at least, the Cuyahoga sediments under cover in southeastern Ohio may be coarser than they have been described. However, it does not appear necessary to assume that the Cuyahoga under cover to the southeastward must be made up of similarly coarse sediments over wide areas. A great deal of coarse material, such as is found in either of these facies, might be transported through a relatively much smaller channel in fine-grained deltal sediments of an earlier stage of accumulation. To account for the conditions in this way would probably necessitate the assumption that there was a change in the nature of the material transported toward increasing coarseness, aggradation in proportion, and a consequent building out over the subaerial portion of the delta of a sandstone member of some thickness, but this thickness, it appears, would be thin in the lower courses of the delta.

The Vanceburg sandstone facies.—The Vanceburg facies was accumulated under conditions different from those of the Toboso and Hocking Valley conglomerate facies. Nevertheless, it probably represents a phase of the same deltal action. Without much doubt the source was to the south-southeastward; it is not, however, inclined structure which indicates this, but the increase in the relative amount of sandstone in that direction. At one time the writer believed that the deposits of this facies were the offshore accumulations on the east side of the Cincinnati dome and that they were evidence that the dome at that time was land area. The rapid westward thinning of the Henley shale member at the base of the Cuyahoga supported this, and indeed, so far as the writer can see, can be interpreted only as indicating that the dome was at least an appreciable topographic feature on the ocean floor at the beginning of Cuyahoga time. It does not now appear, however, that the sandstone of the Vanceburg facies can be interpreted as evidence of a shore near by to the westward. The fact that in Kentucky, within a few miles of the Ohio River, a pure shale facies is found lying to the westward of this sandstone area with no red shale demonstrates that its general nature is that of a lobe of sandstone, pushed out into open water from the mouth of a stream or other definite source of sand, not an alongshore sand deposit. Indeed, nothing has been observed anywhere in Ohio or Kentucky which suggests that land lay to the westward in the region of the Cincinnati dome.

It is possible that local conditions, for example stronger wave- and ocean-current action, will explain the structures found in these sandstones, so widely different from those of the conglomerate facies. But better still is the assumption that the stream currents (or whatever other local current may have been the source) that fed these sands were far weaker than in the Hocking Valley and Toboso areas; the wave-action being the same, under such conditions the feeble waves of this sea might well have been better able to distribute the fine sands brought in at this point, whereas in the conglomerate areas the stronger feeding currents, with their loads of coarse pebbly sand, locally dominated over the wave-action.

The source of the material.—It is of interest to note the nature of the nearest sediments of this age which are exposed to the southeastward and southward as a possible source of the material. The Waverly formations occupy the same interval in the geological column as the Pocono sandstone formation of the Appalachians and are generally regarded as its approximate equivalent. The Pocono sandstone is exposed in various belts in the Appalachians from the anthracite fields southwestward through central Pennsylvania, the western part of Maryland, and on both sides of the boundary line between Virginia and West Virginia to a point in Virginia south of the southern part of the last-named state.

The following paragraph is presented as a brief summary of the published accounts of the Pocono in this region and of a new interpretation of the members forming it; it appears that the irregularity in thickness and composition of the Pocono at various points in northeastern West Virginia can be understood on the theory that there was there erosion of its beds to the extent of 1,100 or 1,200 feet prior to the laying down of the Greenbrier limestone.

It appears that the Pocono in northern Virginia, western Maryland, and south-central Pennsylvania consists of four members (a fifth higher member has been reported from a single locality), of which the second one in ascending order is a prominent gray or white conglomeratic sandstone, the Purslane sandstone.[1] It appears that this sandstone-conglomerate member is the one which comprises almost the whole of the so-called Pocono in its thinned more westerly outcrops along the line between Virginia and West Virginia and in West Virginia, and that there the underlying member has heretofore generally been included with the Catskill.[2] In western and southwestern Virginia, three members have long been recognized[3] which, it appears, correspond very closely to the uppermost three in northern Virginia (excluding the seldom-observed highest member), and the massive conglomerate sandstone at the base in southwestern and western Virginia corresponds exactly with the second member or Purslane sandstone to the northward. It further appears that there is beneath this sandstone in western and southwestern Virginia a member, closely corresponding to the lowest member or Rockwell to the northward, which has been doubtfully referred both to the Pocono and to the Catskill, more latterly to the Catskill. So far as the writer is aware, this correlation between the members in northern Virginia and those seen to the southwestward has not before been suggested. If it is a correct one, then the Purslane sandstone member, the second member in northern Virginia, becomes important, not only as a very persistent member along the Appalachian belt, but as the only member of the Pocono along the line of the Appalachian mountains that is comparable with the coarse sandstones and sandstone conglomerates of the Cuyahoga along the Waverly outcrop belt in Ohio. When it is further recalled that the structure of these Cuyahoga sandstones and conglomerates proves that they were derived from the south-southeastward, and that the axes of the facies point in the same direction, the possible correlation with the Purslane becomes doubly suggestive. It remains to question whether the whole of the Cuyahoga sandstones should be correlated with the Purslane, or only the upper or Black Hand member, which alone is notably conglomeratic. The question is at present too uncertain a one to discuss, but if it be found that the Black Hand alone should be so correlated, the broad extent of the member would be the only cogent argument yet put forward for the separation of the Black Hand from the remainder of the Cuyahoga sediments.

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[1] G. W. Stose, Pawpaw-Hancock Folio, No. 179, *U.S.G.S.*, 1912.

[2] Piedmont, Accident-Grantsville, Franklin, Staunton, Monterey, Buchannon Folios, *U.S.G.S.*

[3] W. M. Fontaine, *Am. Jour. Sci.*, 3d ser., XIII (1877), 115–16; J. J. Stevenson, *Bull. Geol. Soc. Am.*, XIV (1903), 29, and citations there given.

LOGAN FORMATION

The simplicity of lithological structure and stratigraphy of the Logan formation is in marked contrast with the extreme variability which is found in the several facies of the Cuyahoga. With the opening of Logan time, the localization of conditions which resulted in widely different sediments in closely adjacent areas during Cuyahoga time gave way to quite uniform conditions over the whole of the southern Ohio Waverly belt. Extreme areal variation with no very important variation in vertical succession was succeeded by widespread areal uniformity and a threefold vertical subdivision which can be recognized from the Ohio River to the center of the state and probably well into northern Ohio.

Subdivisions and extent.—The three subdivisions of the Logan formation in descending order are as follows: Vinton member, Allensville member, Byer member.

It is possible that a fourth member should be recognized. E. B. Andrews in 1878 proposed that certain beds at the top of the Logan formation at Rushville be designated the Rushville[1] group. There are there shown 22½ feet of rather soft argillaceous shales, gray or red in color, of a type quite different from the bulk of the sandy sediments that compose the Logan, and a pink crinoidal sandy limestone one foot thick. These beds are stratigraphically much higher than those which usually form the top of the Logan. This is because the pre-Pennsylvanian erosion surface here stands, relative to the beds it cuts, much higher than in most places. In addition, these beds were stated by Whitfield to show certain faunal peculiarities that, if verified, will distinguish them from the remainder of the Logan. The fauna has been extensively collected but no statement can be made as yet.

Although the three members listed above are found throughout the length of the Logan belt from central Ohio to the Ohio River, they are not present throughout its entire breadth, as is shown by the map (see Part I) of the known distribution of the Allensville member. In Scioto County the western limit of this bed is quite definitely known. In Pike and Ross counties its absence from the western half of the Logan belt is not demonstrated because of covered slopes and absence of outcrops, but such absence is very strongly suspected. It is in part on the presence of this member that the subdivision depends. The upper member is occasionally absent because of erosion prior to the deposition of the Pennsylvanian or Coal Measures; yet more rarely all three have been removed.

The lower and upper members are fine-grained sandstone and shale deposits, the result of quiet, uniform conditions; the Allensville bed is a very coarse sandstone, or perhaps it would better be called a fine pebble bed, the result of an interval of contraction of the basin. The whole is marine throughout, although faunal remains may be rare.

The Byer member.—This is usually a fine-grained sandstone. Its beds are seldom over 18 inches thick and may tend to split up into thinner beds. In southern Ohio, and especially in the more westerly outcrops, portions of it are better described as shaly sandstone or sandy shale. Even where it is wholly a sandstone there is enough clay present to make the sandstones soft. The color as seen on the outcrop is almost invariably yellow or buff, but under sufficient cover it is probably always a shade of blue or gray. At two points only within the area herein considered is it sufficiently massive to be quarried, at Newark and at Granville in Licking County. At the former locality the beds may attain a thickness of three or four feet.

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[1] *Am. Jour. Sci.*, 3d ser., XVIII (1879), 137.

The member is named from the town of Byer in the northern part of Jackson County where it is well shown in the railroad cuts east of the village. It agrees very closely in its upper and lower limits with the Division II or Kinderhook of Herrick, and with that portion of Prosser's Black Hand at Newark lying between Conglomerate I (the Berne member) and Conglomerate II, the latter one of the beds of the Allensville member.

The coarseness of the material is influenced appreciably by the presence below it of the conglomerate masses of the Cuyahoga, especially in Licking County. The thickness has been considerably influenced. Over the northern counties, Licking, Fairfield, Hocking, and Vinton, where conglomerate sandstones constitute the most of the Cuyahoga and the thickness is correspondingly great, the Byer member is much thinner than farther south in Ross, Pike, Jackson, and Scioto counties. Where the two conglomerate areas are thickest it is 25–30 feet thick; over the intervening Granville province, where the thickness of the Cuyahoga is somewhat reduced, it is commonly about 50 feet and at one point it reaches 80 feet. Westward and southwestward from the great Hocking Valley conglomerate area, as the thickness of the Cuyahoga decreases with its passage into shale the thickness of the Byer member steadily increases from 23 feet to at least 154 feet in eastern Pike County.

The tendency of the Byer sandstones to pass into shales toward the westward, although noticeable in Ross, Pike, and Scioto counties, is most pronounced along the Ohio River. There, between Sciotoville and Portsmouth, the lower portion, to a thickness of at least 75 feet and perhaps more, passes into shales which are not distinguishable from the body of the Cuyahoga shales of the Scioto shale facies and which have been considered the upper part of the Portsmouth member of the Cuyahoga. This tendency on the part of the Byer sediments suggests strongly that its material was also derived from the eastward and southward, in spite of the thinning of the formation to the eastward.

It is not possible to say to what extent the member continues to thicken westward because of the disappearance of the Allensville member in that direction just where the Byer passes into shales and sandstones which are lithologically so similar to those of the Vinton member as to be indistinguishable from them.

The Byer member was formed during a period of quiet sedimentation. The shoreline lay far enough to the eastward so that the outcrop belt of central and southern Ohio was wholly outside the zone of continual shifting of sands by currents and waves, and beyond the reach of delta or sand-spit accumulations such as are seen in the Cuyahoga. Sharp contacts between beds are seldom observed where shaly sandstones make up a considerable part of the succession, the change from sandstone beds through shaly sandstones to shale beds being almost always a gradational one. Well-defined bedding-planes are more likely to be found in those portions made up almost entirely of sandstones and where the material is slightly coarser, as in central Ohio. Although the conditions of sedimentation are best described as quiet, the abundant sediment making up the member was probably swept to its present position and distributed largely by gentle current-action and not by subsidence from mechanical suspension in the water. The material is too coarse to be carried any distance in that way. The presence of such gentle current-action is shown, for example, (1) by frequent cross-bedding in the finest material with long, gently sweeping stratification planes, and (2) by the local sweeping together into a heap of such an odd aggregation of species and abundance of individuals as was found in three cubic feet in a certain bed at Sciotoville, which is otherwise practically barren of fossils, although excellently shown for half a mile and 30 feet thick.

If the correlations made by Cooper in sections to the northward be accepted, the Byer member continues little changed and from 25 to 40 feet thick for at least 55 or 60 miles to the northward of central Ohio, into Wayne County.[1] This is to within 40 miles of Lake Erie.

The Allensville member.—The quiet conditions of Byer time were terminated by general shoaling of the region which resulted in the formation of the Allensville bed, whose chief characteristic is its coarse sandstones. Over much of the area this was brought about gradually, since there is a transition from one to the other; in fact, the typical sandstones of the Byer type are found almost to the top of the Allensville.

The name Allensville is given from numerous outcrops near that village in the western part of Vinton County, although the bed is not especially well developed there nor any better exposed than at other points. As is shown on the map (see Part I), it is found from the Ohio River as far north as the work has been pushed. In Scioto County along the river it is known certainly that it disappears westward, thus demonstrating that the source of its material lay to the eastward. In Pike and Ross counties this westward disappearance has not been completely demonstrated because of poor outcrops, but it is almost certain.

The greatest thickness yet observed is 39 feet, reported by Mr. Schroyer in Pike County, but this is exceptional. Commonly it is from 15 to 25 feet throughout the whole area but not infrequently it is less. It is least on the Ohio River near its extreme western limit where it diminishes rapidly from 6 feet to as many inches just before its final disappearance. The bed is apparently present at every point within the area of its occurrence indicated on the map.

As just noted, its chief characteristic is the occurrence of very coarse, excellently assorted, and usually well-rounded quartz grains. South of Fairfield County the material of the coarse beds is really a fine conglomerate of excellently assorted pebbles from one-sixteenth to one-eighth of an inch in diameter. The coarse beds there first appear in the section as thin layers, often only an inch or less in thickness, between much thicker beds of the typical, Byer-like sandstones. It is very difficult exactly to locate the base if the outcrops are poor. Much of the lower part of the member might well be considered the last stage of the Byer, but the lowest occurrence of the coarse beds has been adopted as the base of the member, even though this may not be the same particular streak that has been observed at the supposed base in a closely adjacent section. The coarse beds become more numerous and thicker in passing upward and usually make up the greater part of the upper half of the member. The topmost 3–5 feet of the member are almost invariably made up of these coarse sands to the almost complete or complete exclusion of the fine-grained material. At all points these coarse deposits carry unusually large amounts of iron, their cement being largely limonitic. This feature alone is often sufficient to identify the horizon. In southern Ohio, beyond the fact that the topmost bed is always the thickest, it is not possible to recognize the beds from section to section.

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[1] *Bull. Sci. Lab. Dennison Univ.*, V (1890), 24–32.

In Fairfield and Licking counties the material is noticeably finer. Whereas to the southward the beds may be described as made up of small pebbles, from Hocking County northward the component material can only be called coarse sand. The assortment is good and there is no notable admixture of the coarser material except in certain limited beds.

In eastern Fairfield County and central and eastern Licking County a characteristic feature of the member is the remarkable persistency of its beds. In its thickness of 15–25 feet, four distinct submembers can be recognized, all more or less persistent and with more or less distinct faunules. This condition is not found to the southward. Following is the section of the Allensville member as exposed in the Vogelmeir quarry at Newark; beds 1, 2, 4, and 5 can be recognized with considerable variation from Rushville to Newark, beyond which they have not been followed. Both Nos. 4 and 5 are likely to have lenses of coarse sand developed in them extensively and No. 5 at Rushville is largely of such coarse material.

	Ft.	In
5. Moderately fine-grained, irregularly bedded, yellow sandstones with numerous beds of coarse, reddish, iron-stained sandstone, the last mostly in the upper half, fossiliferous	14	
4. Bluish-gray, argillaceous shale, little grit, fossiliferous	3	9

	Ft.	In.
3. Coarse quartz sandstone, grains well sized and rounded, white in color, harder and with much less iron than the other beds. This is Conglomerate II of Herrick and the bed which forms the top of the Black Hand in Prosser's description of this section		½–6
2. *Allerisma winchelli* horizon, a hard, bluish, gritty shale with a considerable fauna, chiefly of lamellibranchs and abundant *Spirophyton* markings, one of the most important horizons in central Ohio	5	
1. Very coarse, loosely coherent, reddish sandstone, grains uniformly sized and all about one millimeter in diameter, rounded or subangular. Lower surface slightly irregular	1	4

Evidence of erosion of the underlying beds before some of the coarse members were laid down is not unusual. Both at Rushville in Fairfield County and at Newark the topmost bed of the Byer sandstone had been eroded slightly before the basal bed of the Allensville was laid down. The fossils in the *Allerisma* shales are practically always found in the attitude which they maintained during life, the shells of *Prothyris* standing vertically with the anterior end downward, the shells of *Allerisma*, *Grammysia*, and *Sphenotus* standing obliquely with the anterior end downward. At Newark these shells have been observed at the top of the *Allerisma* shale with the upper portion beveled off at the contact with the overlying coarse bed (Conglomerate II). Evidence of erosion is also seen at the base of some of the higher coarse lenses when they are well developed. Obviously the erosion observed in connection with most of these beds is local. This urges caution in accepting the erosion which took place prior to the formation of the lowest bed as any more important. It is, however, probably of somewhat greater significance since in central Ohio it inaugurated an abrupt change in conditions of sedimentation. In the southern counties no evidence of such erosion has been seen, and the change in the conditions of sedimentation was more gradual. Among numerous interesting problems is the occurrence of these slight erosion surfaces associated with the finer beds of the member, whereas to the southward where the beds are coarser the evidence of erosion, if present at all, is less prominent.

Curious and probably of considerable significance is the manner in which the Allensville bed disappears from the column in southern

Ohio. At Slocum Station, 2½ miles east of Sciotoville, the Allensville bed is well developed, with a thickness of 13 feet 4 inches. Of this the uppermost 4 feet 3 inches are composed almost wholly of the typical fine conglomerate which characterizes this member in southern Ohio. Three-fourths of a mile southwest of this locality only 2 inches of typical Allensville pebble material is present in a section sufficiently clear to show that no other beds of this type are present. A mile and a quarter west of Slocum Station only the merest trace of the Allensville member is present in the form of a few quartz pebbles of usual size in a 2-inch zone of fine-grained sandstone. At Sciotoville there is no evidence of its presence or suggestion of its proper horizon, although repeated search has been made for it in good sections. Not only are the pebbles wanting from this section, but there is no bed of coarse sandstone or bed of any description, which by any character suggests that it may be the westward extension of the Allensville bed. That member completely disappears from the Logan formation certainly within 3½ miles and probably within 2 miles, with no tendency to grade into finer beds.

The Vinton member.—This is the youngest member of the Waverly series. How much more there may have been at one time is not known, since the Vinton is limited upward at all points, where it has not been entirely removed, by an erosion surface, a horizon of great unconformity.

The Vinton member is named from Vinton County, where it is well developed, although not nearly so well developed as elsewhere. It is a series of fine-grained gray or yellowish sandstones and shales. It differs from the typical Byer in the presence of shale beds and in the thinner bedding and more platy nature of the somewhat harder sandstones. However, as noted under the Byer member, these members come to resemble each other very closely in southern Ohio.

Although no especial effort has been made to trace them, it is very evident that certain of the beds composing this member are quite persistent areally. This not only indicates the uniformity of conditions which prevailed but may have yet a greater significance, since there is considerable faunal difference in certain of the different beds. For example, at the base of the formation from central Licking County southward at least as far as western Vinton County, a distance of 55 miles, there is a 30- to 40-foot bed of sandy shales with no particular faunal characters noted as yet. It is overlain at all points by a bed of fine-grained yellow sandstones with an abundant fauna, of which one of the chief species is a *Productus*, heretofore described as, but distinct from, *Productus arcuatus* Hall.

The Vinton member marks the resumption of conditions of quiet, uneventful deposition in deeper water, following the period of shoaling which resulted in the formation of the Allensville member. There is no transition from the one to the other. The shales of the former rest abruptly on the coarse beds of the latter at all points, and this contact is one of the sharp and persistent ones in the Waverly series. It is suspected that its significance as a stratigraphic horizon is more or less in proportion to this prominence.

The thickness of the Vinton is determined wholly by the attitude of the post-Waverlian erosion plane. Valleys of considerable depth were cut into the Waverly following its deposition and prior to the accumulation of the Pennsylvanian deposits, or Coal Measures, and considerable irregularity can be detected in its upper surface as a result. The greatest known thickness of the member is preserved in the northwest portion of Perry County and adjacent parts of southern Licking County. Here was an area which must have been uniformly high land, for the Vinton member is from 200 to 240 feet thick, although it does not usually much exceed 50–75 feet thick, and is occasionally wholly removed. On the Ohio River between Sciotoville and Portsmouth the member probably attains a similar thickness, but precise determination is seriously hampered by the absence of the Allensville member. The Mississippian-Pennsylvanian contact in central and southern Ohio has been briefly described.[1]

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[1] J. E. Hyde, "Notes on the Absence of a Soil Bed at the Base of the Pennsylvanian of Southern Ohio," *Am. Jour. Sci.*, 4th ser., XXXI (1911), 557–60.